CHAPTER 12

Applying Biomechanics in Sports Medicine and Rehabilitation

Biomechanics also helps professionals in clinical settings to determine the extent of injury and to monitor progress during rehabilitation. Many sports medicine programs have specific evaluation and diagnostic systems for identification of musculoskeletal problems. The physical therapist and athletic trainer analyzing walking gait or an orthopaedic surgeon evaluating function after surgery all use biomechanics to help inform decisions about human movement.

These clinical applications of biomechanics in qualitative analysis tend to focus more on localized anatomical issues than the examples in the previous three chapters. This chapter cannot replace formal training in gait analysis (Perry, 1992), injury identification (Shultz, Houglum, and Perrin, 2000), or medical diagnosis (Higgs & Jones, 2000). It will, however, provide an introduction to the application of biomechanical principles in several sports medicine professions. Biomechanical principles must be integrated with the clinical training and experience of sports medicine professionals.

INJURY MECHANISMS

Most sports medicine professionals must deduce the cause of injuries from the history presented by patients or clients. Occasionally athletic trainers may be at a practice or competition where they witness an injury. Knowledge of the biomechanical causes of certain injuries can assist an athletic trainer in these situations, in that diagnosis of the particular tissues injured is facilitated. Imagine you are an athletic trainer walking behind the basket during a basketball game. You look onto the court and see one of your athletes getting injured as she makes a rebound (see Figure 12.1). What kind of injury do you think occurred? What about the movement gave you the clues that certain tissues would be at risk of overload?

The athlete depicted in Figure 12.1 likely sprained several knee ligaments. Landing from a jump is a high-load event for the lower extremity, where muscle activity must be built up prior to landing. It is likely the awkward landing position, insufficient pre-impact muscle activity, and twisting (internal tibial rotation) contributed to the injury. It is also likely that the anterior (ACL) and posterior (PCL) cruciate ligaments were sprained. The valgus deformation of the lower leg would also suggest potential insult to the tibial (medial) collateral ligament. Female athletes are more likely to experience a non-contact ACL injury than males (Malone, Hardaker, Garrett, Feagin, & Bassett, 1993), and the majority of ACL injuries are non-contact injuries (Griffin *et al.*, 2000). There are good recent reviews of knee ligament injury mechanisms (Bojsen-Moller & Magnusson, 2000; Whiting & Zernicke, 1998).

You rush to the athlete with these injuries in mind. Unfortunately, any of these sprains are quite painful. Care must be taken to comfort the athlete, treat pain

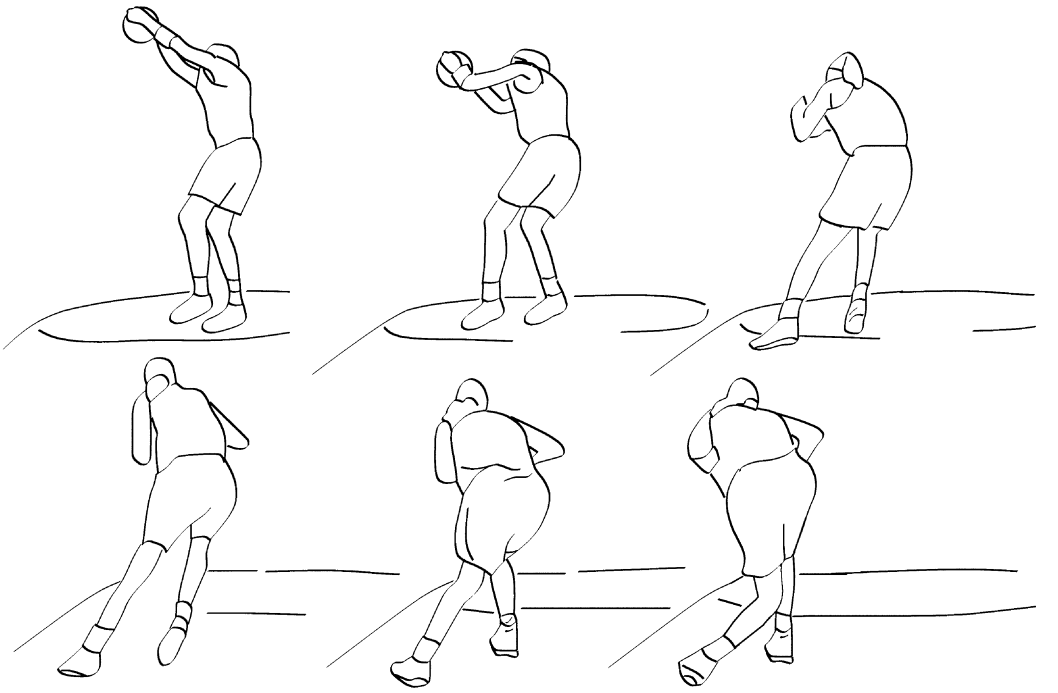

Figure 12.1. A basketball player injuring her knee during a rebound.

and inflammation, and prevent motion that would stress the injured ligaments. Joint tests and diagnostic imaging will eventually be used to diagnosis the exact injury. What biomechanical issue or principle do you think was most influential in this injury?

EXERCISE SPECIFICITY

The principle of specificity also applies to therapeutic exercise in rehabilitation settings. The exercises prescribed must match the biomechanical needs of the healing patient. Exercises must effectively train the muscles that have been weakened by injury and inactivity. Biomechanical research on therapeutic exercise is even more critical since therapists need to know when internal loadings may exceed the mechanical strengths of normal and healing tissues.

Imagine that you are a physical therapist treating a runner with patellofemoral pain syndrome. Patellofemoral pain syndrome (PFPS) is the current terminology for what was commonly called chondromalacia patella (Thomee, Agustsson, & Karlsson, 1999). PFPS is likely inflammation of the patellar cartilage since other knee pathologies have been ruled out. It is believed that PFPS may result from misalignment of the knee, weakness in the medial components of the quadriceps, and overuse. If the vastus medialis and especially the vastus medialis obliquus (VMO) fibers are weak, it is hypothesized that the patella may track more laterally on the femur and irritate either the patellar or femoral cartilage. The exercises commonly

prescribed to focus activation on the VMO are knee extensions within 30° of near complete extension, similar short-arc leg presses/squats, and isometric quadriceps setting at complete extension, and these exercises with combined hip adduction effort. While increased VMO activation for these exercises is not conclusive (see Earl, Schmitz, and Arnold, 2001), assume you are using this therapeutic strategy when evaluating the exercise technique in Figure 12.2. What biomechanical principles are strengths and weaknesses in this exercise.

Most biomechanical principles are well performed. Balance is not much of an issue in a leg press machine because mechanical restraints and the stronger limb can compensate for weakness in the affected limb. There is simultaneous Coordination, and there appears to be slow, smooth movement (Force–Time).

The principle that is the weakest for this subject is the large knee flexion Range of Motion. This subject has a knee angle of about 65° at the end of the eccentric phase of the exercise. This very flexed position puts the quadriceps at a severe mechanical disadvantage, which results in very large muscle forces and the consequent large stresses on the patellofemoral and tibiofemoral joints. This exercise technique can irritate the PFPS and does not fit the therapeutic strategy, so the therapist should quickly instruct this person to decrease the range of motion. Providing a cue to only slightly lower the weight or keeping the knees extended to at least 120° would be appropriate for a patient with PFPS.

A better question would be: should this person even be on this leg press machine? Would it be better if they executed a different exercise? A leg press machine requires less motor control to balance the resistance than a free-weight squat exercise, so a leg press may be more appropriate than a squat. Maybe a more appropriate exercise would be a leg press machine or a cycle that allows the subject to keep the hip extended (reducing hip extensor contributions and increasing quadriceps demand)

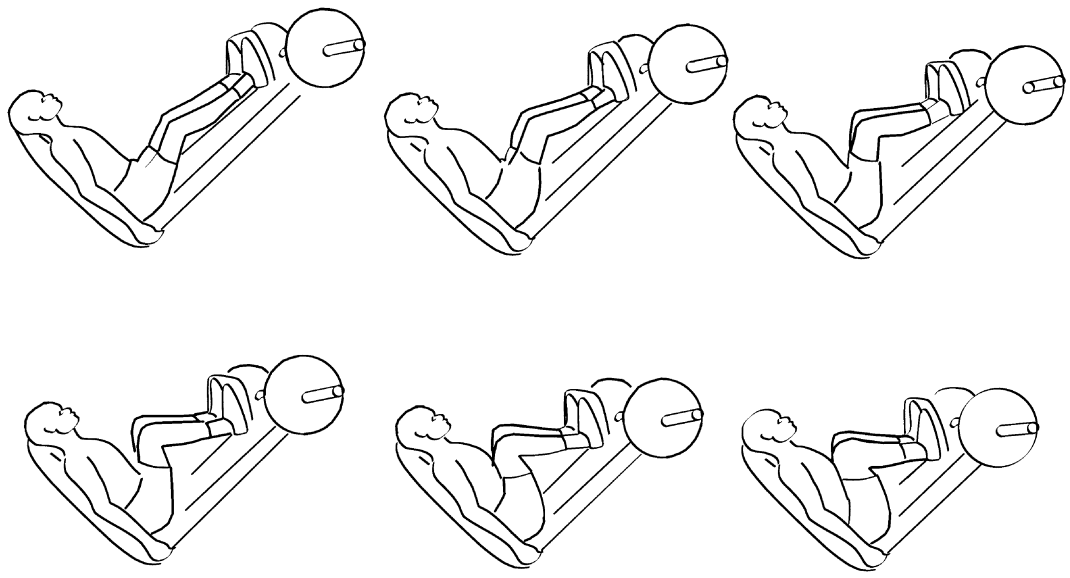

Figure 12.2. The leg press technique of a person trying to remediate patellofemoral pain.

and limit the amount of knee flexion allowed. The differences in muscle involvement are likely similar to upright versus recumbent cycling (Gregor, Perell, Rushatakankovit, Miyamoto, Muffoletto, & Gregor, 2002). These subtle changes in body position and direction of force application (Force– Motion) are very important in determining the loading of muscles and joints of the body. Good therapists are knowledgeable about the biomechanical differences in various exercises, and prescribe specific rehabilitation exercises in a progressive sequence to improve function.

EQUIPMENT

Sports medicine professionals often prescribe prosthetics or orthotics to treat a variety of musculoskeletal problems. Prosthetics are artificial limbs or body parts. Orthotics are devices or braces that support, cushion, or guide the motion of a body. Shoe inserts and ankle, knee, or wrist braces are examples of orthotics. Orthotics can be bought "off the shelf" or custom-build for a particular patient.

Shoe inserts are a common orthotic treatment for excessive pronation of the subtalar joint. One origin of excessive pronation is believed to be a low arch or flat foot. A person with a subtalar joint axis below 45° in the sagittal plane will tend to have more pronation from greater eversion and adduction of the rear foot. It has been hypothesized that the medial support of an orthotic will decrease this excessive pronation.

Figure 12.3 illustrates a rear frontal plane view of the maximum pronation position in running for an athlete diagnosed with excessive rear-foot pronation. The two images show the point of maximum pronation when wearing a running shoe (a) and when wearing the same shoe with a custom semirigid orthotic (b). Imag-

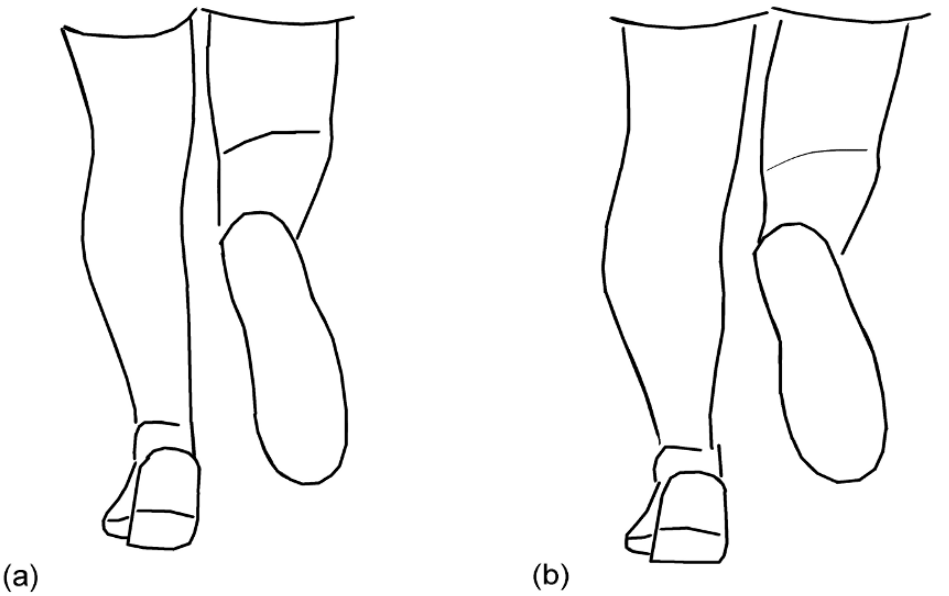

Figure 12.3. Rear frontal plane view of the positions of maximum pronation in running in shoes (a) and shoes with a semi-rigid orthotic (b) on a treadmill at 5.5 m/s.

ine that you are the athletic trainer working with this runner. The runner reports that it is more comfortable to run with the orthotic, an observation that is consistent with decreased pain symptoms when using orthotics (Kilmartin & Wallace, 1994). You combine this opinion with your visual and videotaped observations of the actions of her feet in running.

Inspection of Figure 12.3 suggests that there is similar or slightly less pronation when the runner is wearing an orthotic. Biomechanical research on orthotics and rear-foot motion have not as of yet determined what amount of pronation or speed of pronation increases the risk of lower-extremity injuries. The research on this intervention is also mixed, with little evidence of the immediate biomechanical effects of orthotics on rear-foot motion and the hypothesized coupling with tibial internal rotation (Heiderscheit, Hamill, & Tiberio, 2001). In addition, it is unclear if the small decrease in pronation (if there was one) in this case is therapeutic. The comfort and satisfaction perceived by this runner would also provide some support for continued use of this orthotic.

READINESS

Orthopaedic surgeons and athletic trainers must monitor rehabilitation progress before clearing athletes to return to their practice routine or competition. Recovery can be documented by various strength, range-of-motion, and functional tests. Subjective measures of recovery include symptoms reported by the athlete and qualitative analyses of movement by sports medicine professionals. Athletes will often be asked to perform various movements of increasing demands, while the professional qualitatively evaluates the athlete's control of the injured limb. A couple of common functional tests for athletes with knee injuries are multiple hops for distance or time (Fitzgerald *et al.*, 2001).

Imagine you are an athletic trainer working with an athlete rehabilitating an ACL injury in her right knee. You ask the athlete to perform a triple hop for maximum distance. The technique of the first hop is illustrated in Figure 12.4. As you measure the distance hopped, you go over the strengths and weaknesses in terms of the biomechanical principles of the hop in your mind. Later you will combine this assessment with the quantitative data. The distance hopped on the injured limb should not be below 80% of the unaffected limb (Fitzgerald *et al.*, 2001). What biomechanical principles are strengths and weaknesses, and what does a diagnosis of this hopping performance tell you about her readiness to return to practice? Biomechanical technique is just one aspect of many areas that must be evaluated in making decisions on returning athletes to play (Herring *et al.*, 2002).

Most all biomechanical principles are well performed by this athlete. This athlete is showing good hopping technique with nearly Optimal Projection for a long series of hops. She shows good Coordination of arm swing, integrated with good simultaneous flexion and extension of the lower extremity. She appears to have good Balance, and her application of the Range-of-Motion and Force–Time principles in the right leg shows good control of eccentric and concentric muscle actions. There are no apparent signs of apprehension or lack of control of the right knee. If these qualitative observations are consistent with the distance measured for the three hops, it is likely the athletic trainer would clear this athlete to return to practice. The therapist might ask the coach to closely monitor the athlete's initial practices for signs of apprehension, weakness, or poor technique as she begins more intense and sport-specific movements.

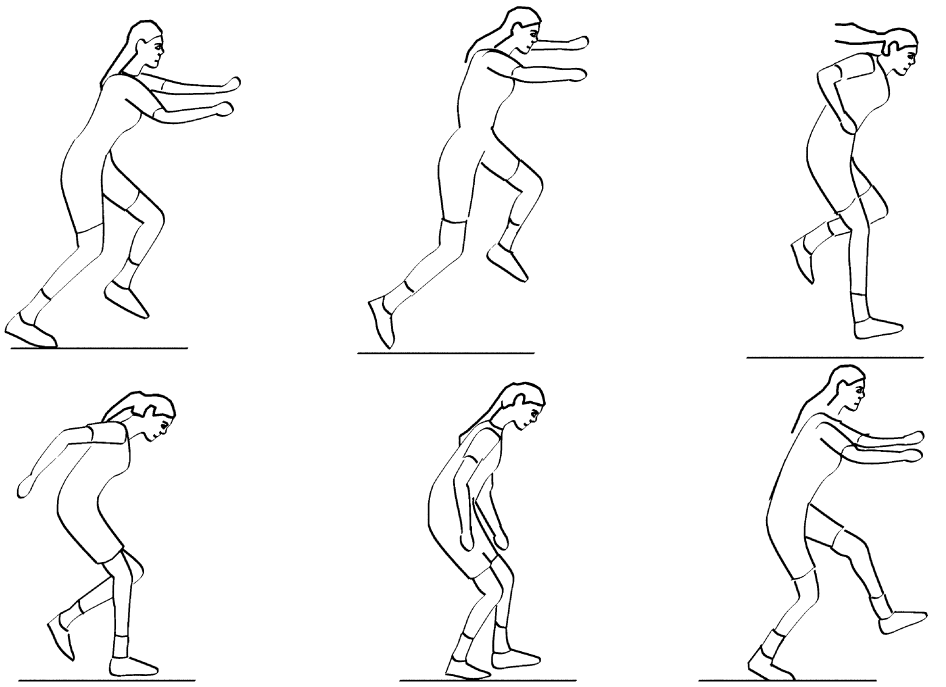

Figure 12.4. An athlete doing a triple hop test.

INJURY PREVENTION

This chapter opened with the scenario of one of the most common injuries in sports, a non-contact sprain of the ACL. The large numbers of injuries to young female athletes has resulted in considerable research on how these injuries occur in landing, jumping, and cutting. Many biomechanical factors have been hypothesized to be related to increased risk of ACL injuries in sport: peak vertical ground reaction force, knee flexion angle at landing, hamstring strength, and balance. A large prospective study of the biomechanics of landing in female adolescent athletes who then participated in high-risk sports has recently identified several variables that are associated with risk of ACL injury (Hewitt *et al*., 2005). The variables that were associated with girls that became injured were greater knee abduction angle (lower leg valgus), and greater ground reaction force and knee abduction moment. It is possible that as girls enter adolescence the increased risk of ACL injuries comes from dynamic valgus loading at the knee that results from a combination of factors. With adolescence in females the limbs get longer and hips widen, if strength at the hip and knee, coordination, and balance do not keep up with these maturational changes it is likely that risk of ACL injury could be increased.

While sports medicine professionals have qualitatively evaluated the strength and balance of patients in single leg stance and squats for many years, recent papers have proposed that simple two-dimensional measurements of frontal plane motion of the lower extremity in single leg squats might be a useful clinical tool for identifying athletes that may be at a higher risk for

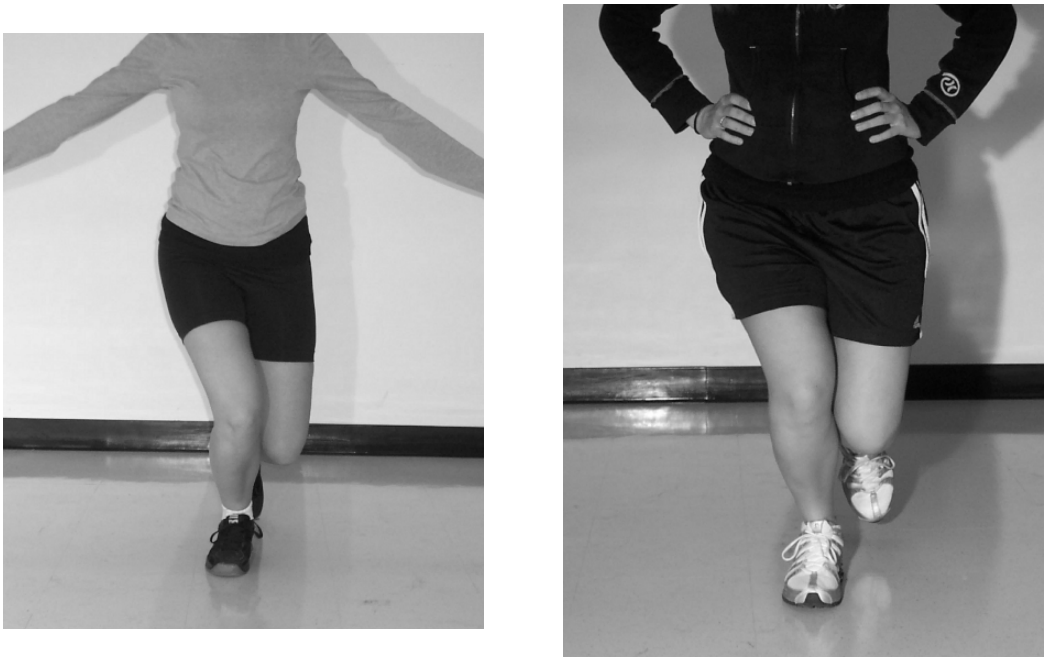

Figure 12.5. Lower leg position of the bottom of a single leg squat for two young athletes.

ACL injury (McLean *et al*., 2005; Wilson, Ireland, & Davis, 2006). While this test is not as dynamic as landing, it is likely a safer screening procedure that also can be qualitatively evaluated. If screening suggests an athlete may be at risk (poor control of knee in the frontal plane), research has shown that preventative conditioning programs can decrease the risk of ACL injuries (see review by Hewitt, Ford, & Meyer, 2006).

Figure 12.5 illustrates the position of the lower extremity at the bottom of a single leg squat for two young athletes. If you were an athletic trainer or physical therapist screening these athletes before a competitive season, which athlete would you be most concerned about for a higher risk of ACL injury? Could you draw on the figure lines along the long axes of the leg and measure an angle representing the valgus orientation of the lower leg? What conditioning would you suggest for this athlete? Would there be any special technique training you would suggest to the coach for jumping, landing, and cutting during practice?

SUMMARY

Sports medicine professionals use biomechanical principles to understand injury mechanisms, select appropriate injury prevention and rehabilitation protocols, and monitor recovery. In the specificity example, we saw that qualitative analysis of exercise technique can help sports medicine professionals ensure that the client's technique achieves the desired training effect. Qualitative analysis in sports medicine often focuses on an anatomical structure level more often than other kinesiology professions. Qualitative analysis of therapeutic exercise also requires an interdisci-

plinary approach (Knudson & Morrison, 2002), especially integrating clinical training and experience with biomechanics. Other issues sports medicine professionals must take into account beyond biomechanical principles are pain, fear, motivation, and competitive psychology.

DISCUSSION QUESTIONS

1. What biomechanical principle do you think is more important in rehabilitating from an ankle sprain, Balance or Range of Motion?

2. Patients recovering from knee injuries are often given braces to prevent unwanted movement and to gradually increase allowable motion. What movement characteristics would indicate that a patient is ready to exercise or function without a brace?

3. Sports medicine professionals looking for the causes of overuse injuries often evaluate joints distant from the affected area (Kibler & Livingston, 2001) because of Segmental Interaction through the kinematic chain. What biomechanical principles can provide cues to potential overuse injuries in other parts of the body?

4. A major injury in athletic and sedentary populations is low-back pain. What abdominal and back muscles are most specific to injury prevention for an office worker and a tennis player?

5. Athletes using repetitive overarm throwing often suffer from impingement syndrome. What biomechanical principles can be applied to the function of the shoulder girdle and shoulder in analyzing the exercise and throwing performance of an injured athlete?

6. You are an trainer working with an athlete recovering from a third-degree ankle sprain. You and the athlete are deciding whether to use athletic tape or an ankle brace. What does a qualitative biomechanical analysis suggest is the better of these two options? What biomechanical studies would you suggest to investigate the clinical efficacy of these options?

7. What biomechanical principles should be focused on when a therapist or trainer is working with elderly clients to prevent falls?

8. An adapted physical educator has referred a young person who might have Developmental Coordination Disorder (DCD) to a physician. Before various imaging and neurological tests are performed, what biomechanical principles should be the focus of observation, and what simple movement tests would be appropriate in the initial physical/orthopaedic exam?

SUGGESTED READING

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WEB LINKS

ACSM—The American College of Sports Medicine is a leader in the clinical and scientific aspects of sports medicine and exercise. ACSM provides the leading professional certifications in sports medicine.
http://acsm.org/

APTA—American Physical Therapy Association
http://www.apta.org/

CGA—International Clinical Gait Analysis website, which posts interesting case studies, discussions, and learning activities.
http://guardian.curtin.edu.au/cga/

FIMS—International Federation of Sports Medicine
http://www.fims.org/

Gillette Children's Hospital Videos and CDROMs
http://www.gillettechildrens.org/default.cfm?PID=1.3.9.1

GCMAS—North American organization called the Gait and Clinical Movement Analysis Society
http://www.gcmas.net/cms/index.php

ISB Technical Group on footwear biomechanics
http://www.staffs.ac.uk/isb-fw/

NATA—National Athletic Trainers' Association
http://www.nata.org/